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Hygroscopicity of Nucleated Nanoparticles in CLOUD 7 Experiments

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Abstract. We investigated hygroscopicity of nucleated nanoparticles derived from dimethylamine and α -pinene with sulfuric acid during CLOUD 7 (Cosmic Leaving Outdoor Droplets) campaign at CERN. The hygroscopicity of nucleated nanoparticles from 10 to 20 nm in mobility diameter was measured with a nano tandem differential mobility analyzer (nano-TDMA). Here, we present preliminary results from the CLOUD 7 experiments.

Keywords: CLOUD, CERN, Nanoparticles, Hygroscopicity, nano-TDMA

PACS: 92.60.Mt

INTRODUCTION

Nanoparticles in the ambient atmosphere are emitted from natural and anthropogenic sources (i.e., primary aerosols) and generated by homogenous reactions among various vapors (i.e., secondary aerosols). It is necessary to determine their physicochemical properties in order to understand the effect of aerosols on Earth's climate change.¹ In the current study, we focus on hygroscopicity of nucleated nanoparticles produced by dimethylamine and α -pinene with sulfuric acid during CLOUD 7 experiments at CERN.² Results from this study can give indirect size-resolved chemical composition information of nucleated nanoparticles.³

METHODS

Nano-TDMA System

The nano tandem differential mobility analyzer (nano-TDMA) was used to measure hygroscopicity of nanoparticles generated inside the CLOUD chamber. The nano-TDMA⁴ consisted of two nano-DMA⁵ (differential mobility analyzer; TSI 3085), a CPC (condensation particle counter; TSI 3785), and humidifiers as shown in Figure 1. The nucleated nanoparticles were dried and then charged by a bipolar diffusion charger (⁸⁵Kr, TSI) before entering first DMA. In the first DMA, particles with certain size (10, 15, and 20 nm) were selected from the charged polydisperse nanoparticles. The selected nanoparticles passed through an aerosol humidifier consisting of

GoreTex tubing. After humidifying, size distribution of nanoparticles was measured with second DMA and CPC.

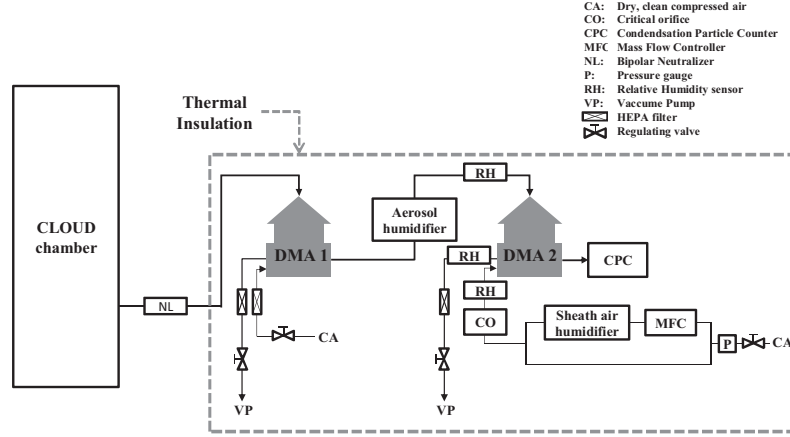


FIGURE 1. A schematic diagram of the nano tandem differential mobility analyzer (nano-TDMA) for measuring hygroscopicity of nucleated nanoparticles.

Before and after CLOUD 7 experiments, we measured hygroscopic growth factor (HGF) and deliquescence relative humidity (DRH) using sodium chloride (NaCl) and ammonium sulfate ((NH₄)₂SO₄) particles of 10 and 20 nm to calibrate our nano-TDMA system.

Hygroscopicity of Nucleated Nanoparticles

Here the hygroscopicity of nucleated nanoparticles was represented by hygroscopic growth factor (HGF) and kappa (κ) value. The HGF was defined as the ratio of geometric mean diameter at humidified condition to that at dry condition. In this study, relative humidity (RH) at humidified and dry condition was around 90% and less than 5% RH, respectively.

$$HGF = \frac{d_{GMD}(humidified)}{d_{GMD}(dry)} \quad (1)$$

Also, κ value could be calculated based on Eq. 2⁶;

$$\kappa = (HGF^3 - 1) \cdot \left[\frac{1}{S} \cdot \exp\left(\frac{4\sigma_w M_w}{RT\rho_w d_{dry} HGF}\right) - 1 \right] \quad (2)$$

where S is the saturation ratio, σ_w is the water surface tension at room temperature, M_w is the molecular weight of water, R is the ideal gas constant, T is the room temperature, ρ_w is the density of liquid water.

PRELIMINARY RESULTS

We present preliminary results from this study. We observed several size and composition dependent features in hygroscopic behavior of the particles. As particle size increased from 10 nm to 20 nm, hygroscopicity decreased regardless of experimental condition. It indicates that chemical composition of nanoparticles was changing with size.³ According to our observation, nanoparticles generated by dimethylamine-H₂SO₄ were more hygroscopic than those produced by α -pinene-dimethylamine-H₂SO₄. This is expected as the hygroscopicity of α -pinene is smaller than that of dimethylamine and sulfuric acid.^{7,8,9} Also, in the presence of α -pinene in the chamber, the hygroscopicity decreased with increasing size indicating increasing fraction of organics in the particles.

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